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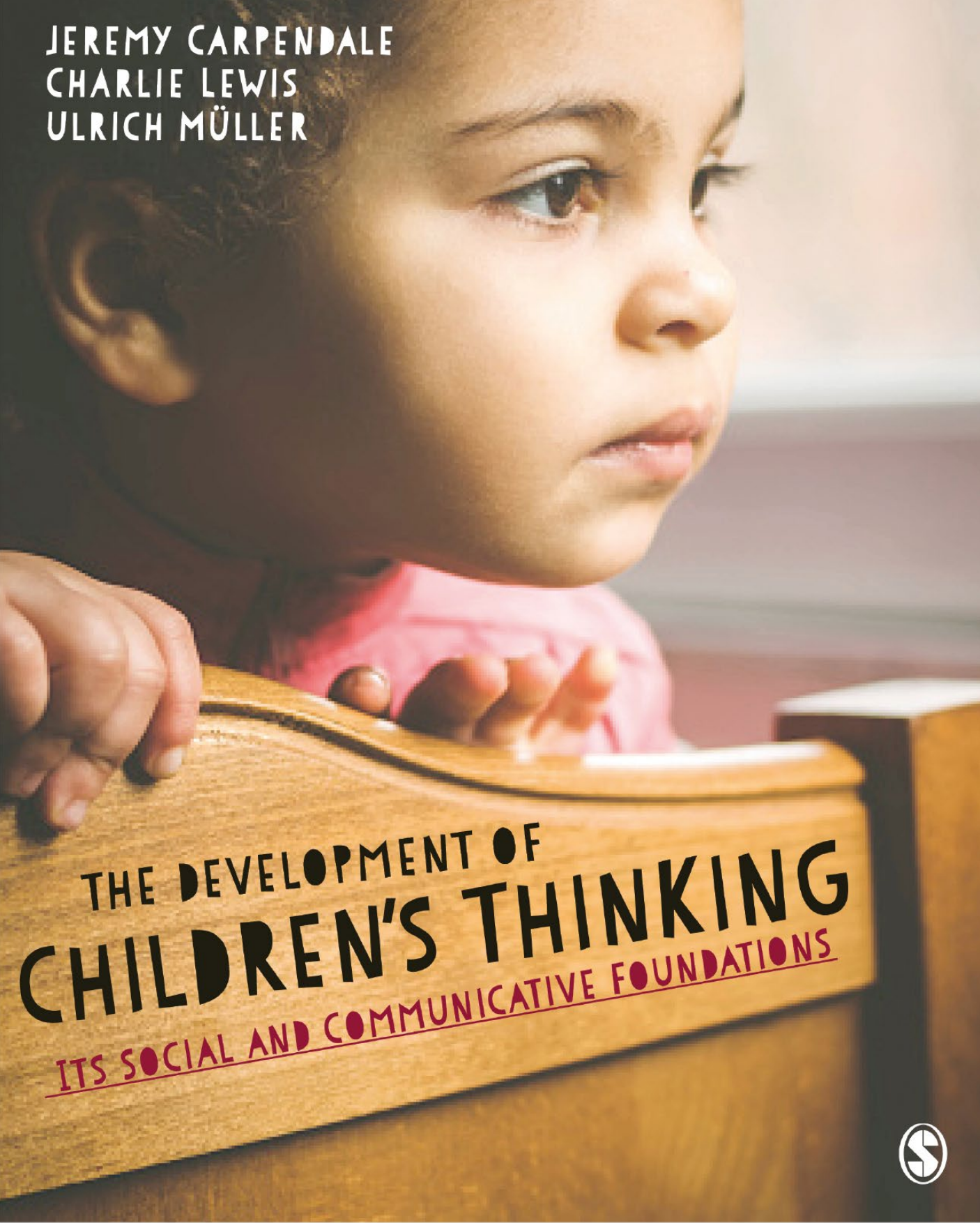

THE DEVELOPMENT OF CHILDREN'S THINKING

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THE DEVELOPMENT OF CHILDREN'S THINKING

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Figure 7.2: Kanzi, language-reared male bonobo, converses with Sue Savage-Rumbaugh in 2006 using a portable "keyboard" of arbitrary symbols that Kanzi associates with words. Photo distributed on Creative Commons Attribution-Share Alike 4.0 International license.

Figures in Chapter 10 are courtesy of Karen Shimmon.

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For Hannah, Max and Deb (JC)

For Rosie, Tom, Camilla, Lyndsey, Laurie and to the memory of Tony (1949–2015) (CL)

For Benjamin, Emily, Nathaniel, and Nadia (UM)

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1 INTRODUCTION: WHAT IS HUMAN THINKING AND HOW DOES IT DEVELOP?

LEARNING OUTCOMES

By the end of this chapter you should:

- Be aware of the topics covered in this book.
- Understand that theories are based on sets of preconceptions.
- Understand the differences between the two worldviews on which many theories are based.
- Be aware of the complexity of how knowledge is acquired and the constructivist view of this process.

As humans we can plan for the future and reflect on the past with pride or regret. We can talk to others about topics ranging from the weather and gossip about friends to the state of the world and what we can do about it. We can reflect on our role in society and how we might improve life for others. How is all of this possible? Although other species are intelligent in many ways, they do not seem to engage in such complex activities. How is it that we as humans have come to understand something about our universe and the life history of stars, as well as reflect on our own intelligence? This is the overall question we explore with its many dimensions. How do human forms of thinking develop? This question, or at least some aspects of it, motivates the careers of many scientists. We will address aspects of this question in our book.

Humans like to think of themselves as a very successful species because they have spread across all of the continents on the planet, and thrived in diverse environments. There is a common perspective that the evolutionary process led from lower to higher forms of life, culminating in human beings, who are ranked on top of all these forms of life. Yet, it is difficult to establish criteria for success and evolutionary progress (for a discussion see Nee, 2005; Rosslenbroich, 2006). It also remains to be seen how long term our success will be, or whether we will continue to ignore signs that we are rapidly making our environment inhospitable for us. Whether humans turn out to be a flash in the pan, destroying what we need to live, is debatable. Kurt Vonnegut (1991, p. xi), the author of several bestselling novels, was not optimistic. He suggested that 'If flying-saucer creatures or angels or whatever were to come here in a hundred years, say, and find us gone like the dinosaurs, what might be a good message for humanity to leave for them, maybe carved in great big letters on a Grand Canyon wall? Here is this old poop's suggestion: WE PROBABLY COULD HAVE SAVED OURSELVES, BUT WERE TOO DAMNED LAZY TO TRY VERY HARD …' (original emphasis). As humans we have used our cognitive abilities to construct technologies that have advanced our ability to rapidly change our environment. But we don't always consider the consequences.

Fundamental to our argument in each chapter is that it is important to take a developmental perspective in order to fully explain aspects of being human such as thinking, language, perception, emotion, and abnormal behaviour. To study development is not to assume that skills come online and need no explanation. The processes involved help us to understand the origins and nature of skills like thinking. There are also practical implications that follow from understanding typical development because this can shed light on cases where there are problems with development as well as having implications for education.

1.1 WHAT IS THIS BOOK ABOUT? A QUICK SURVEY OF THE FOLLOWING CHAPTERS

This book examines key theories and research on how children's thinking develops. A way to frame this question is in terms of how the world comes to be meaningful for children through their biologically embodied interaction with the world and other people (Marshall, 2016). This broad question divides into multiple issues, and we bring out the significance of developmental changes in childhood by organising this book around a series of questions. Questions or problems always come first for scientists, and the same should hold in education. We feel that students need to know why a problem is important. In fact, we often need to be reminded of the significance of everyday experience: this is because 'It would hardly be fish who discovered the existence of water' (Kluckhohn, 1949, p. 11). Fish are supported by and immersed in water, and therefore would take it for granted without noticing it, just as we humans live *in* language, social interaction, and culture,

and, therefore, may have difficulty noticing these aspects of our lives. We take aspects of our world like language for granted, so it is hard to reflect on how language actually works. Ironically, it actually takes skill to notice what is always right in front of us.

We review topics that are usually considered separately, like cognitive development, infant communication, language, social cognitive development, and moral development. This separation of topics follows from a particular theoretical framework, or set of presuppositions, according to which each is viewed as separable from the rest. From our perspective, however, they are fundamentally interrelated and should be presented together. Indeed we go further, to argue that thinking cannot be adequately explained by only focusing on individual minds because the very abilty to think is socially constituted. By this we mean that when we talk about the development of thinking we highlight the crucial role of social interaction, charged by emotion, in this process. The sequence of chapters which follows attempts to unravel the interrelations among the topics covered, as well as describing the research in each 'area' of understanding. Yes, we discuss topics like 'language' or 'moral reasoning' in separate chapters, but we affirm here that we treat these as being part of the same process.

To reflect upon how approaches to development differ, in this chapter we discuss the preconceptions on which two contrasting worldviews are based. We do so by briefly describing the focus of the forthcoming chapters. These sets of preconceptions or views regarding the nature and development of knowledge are referred to as worldviews (Overton, 1991; Overton & Reese, 1973). Any theory in psychology is based on assumptions about our biological level of functioning, but these can originate in radically different theoretical frameworks. In order to evaluate current claims it is necessary to know something about recent developments in biology, which we discuss in Chapter 2. According to a popular claim, infants are born with ready-made ways of thinking. By contrast, current work in biology suggests that this is implausible. Instead, because of the large extent of plasticity in human neural development, ways of thinking and neural pathways are shaped through experience. Therefore, it is essential to study the dynamic interplay between biological functioning and sociocultural context, and to investigate the role of the child's activity in cognitive development. This leads to the chapters on cognitive development in which we review relevant theories dealing with the development of knowledge.

A question that arises from this discussion concerns the nature and development of meaning on which human thinking is based. In the first group of chapters (3 and 4), we examine how infants and young children come to understand the world in their everyday lives. They do so by learning how to interact and how to interpret others' contributions to interaction. We focus on a theory which has dominated developmental psychology over the past ninety years but which has been misunderstood and played down in recent years. This theory considers how knowledge and thinking develop within the child's everyday experience. As a result, it takes an action-based, embodied approach to understand how the emergence of knowledge and thinking must be viewed in terms of the individual's interactions with the world. It begins with simple sensory and motor activity as well

as very primitive feelings and experience with others. We then broaden the focus to consider the role of wider social processes in the child's construction of knowledge. In this discussion we will raise questions such as the importance of preschoolers' talk to themselves in order to reflect on how this might provide insights into how cognitive development takes place.

If social experience is vital in cognitive development how does this process occur? The next group of chapters (5–8) home in on the development of communication and language. To understand how this happens we return in each chapter to views of meaning and its development. This section starts with how infants come to master communicative skills involving gestures such as pointing (Chapters 5 and 6). We continue by reviewing research and theories on language development, using animal communication as a means to investigate the nature of human languages (Chapter 7). The next two chapters (8 and 9) then examine how learning to use sentences and grasp the meaning of words is part of the process by which young children make sense of everyday interactions.

The analysis of language development provides a platform for the next topic, which is how children develop higher-order cognitive processes, currently referred to as executive function (Chapter 10). This is often studied as a window into the workings of the mind-brain system. Yet we suggest that if we wish to understand how children come to gain high-level control over their actions, we need to examine the social constitution of these executive function skills.

In the next group of two chapters (11 and 12) we consider children's thinking about the social world. This is often termed 'social cognition', but recent research on this topic has labelled it 'theory of mind'. However, we prefer the more theoretically neutral description, 'the development of social understanding'. In reviewing research on how children develop social understanding it is important to consider the evidence of strong links to language. Making sense of this research requires examining conceptions of mind and meaning. A crucially important aspect of the vast topic of social understanding is morality – concerning how we treat others. Moral development is the topic of the last two chapters in the book (13 and 14), where we discuss what morality is and how it develops.

It is our conviction that, in order to understand development more fully, we need to approach it from a multidisiplinary perspective. Humans are both biological entities and a highly social species. Consequently, in this book we draw on many other disciplines in addition to developmental psychology, including cognitive science, philosophy, linguistics, biology, neuroscience, evolutionary theory, primatology, sociology, anthropology, and history.

1.2 CRITICISM, DEBATE, AND WORLDVIEWS

In each of the various areas of research reviewed in this book, there is by no means common agreement about the interpretation of the empirical evidence. Instead, competing

theories have been proposed to explain the research findings, and there is thus considerable debate. A careful and critical evaluation of research and theoretical positions is crucial to the scientific enterprise because science is about testing ideas as well as adding to knowledge. The way to build on others' thinking is through careful analysis, which can involve criticism, correction and extension. In the words of Alexander Pope:

> Trust not yourself; but your defects to know,
>
> Make use of every friend – and every foe
>
> (*Essay on Criticism*, 1711, Part II, p. 69)

In other words, critics help in building sound theories by pointing out flaws that need to be addressed. Historians (Kuhn, 1962) and philosophers of science (Popper, 1934/59) have long pointed out that science is a process of continued questioning of competing theories and hypotheses. Developmental psychology is no exception to this rule.

When you come to analyse the theories that we describe, it is essential to be aware of the assumptions on which they are based. Theories are based on sets of preconceptions, known as worldviews. It is important to be aware of these assumptions and the fact that they should be critically evaluated.

For over a century (indeed much longer) 'popular' accounts of psychology have depicted development as either the unfolding of inborn or 'innate' skills, or as a blank slate upon which behaviours are shaped by parents and caregivers. We group these together into one worldview because contemporary nativist and empiricist theories view the mind as fundamentally passive. The mind is conceived of as being a container for mental contents (e.g. beliefs, ideas, representations). The content arrives in the mind through a causal process: the input (e.g. sensory stimulation) triggers a causal process that activates the mental content, which, in turn, causes an output (e.g. movements). A person's mental contents, or ideas, are just the effects of stimuli external to the mind and the mechanical operations or computations triggered by those stimuli. Meaning resides in the mental content; it needs to be accessed by the individual and can then be shared with others. Empiricist and nativist theories lack the idea of an active agent who produces meaning in his or her interactions with the world; the 'person as agent becomes superfluous' (Judge, 1985, p. 51). Sharing the assumption that the mind is passive, the difference between empiricist and nativist approaches then boils down to the issue of whether the computational machinery that intervenes between input and output is innate or learned based on experience.

Both nativism and empiricism start from the taken-for-granted adult experience of having a mind that is private and accessible only to the self. Meaning is encapsulated in the mental content of the individual mind. From a developmental perspective, the problem that the child then faces is how to understand and communicate with others. This perspective has various names. It has been referred to as Cartesian after the philosopher René Descartes (1641/1960), who famously articulated this position in a series of 'meditations'

or reflections on the mind. However, this view has an even longer history and can be traced back to Saint Augustine's *Confessions* written a thousand years before Descartes (Wills, 2001). Augustine (354–430 CE) wrote about what he imagined had been his experience when he was an infant. He claimed to recall that he faced the problem of trying to communicate his desires such as his hunger to others. What Augustine referred to is nowadays known as an individualistic or cognitive perspective. This is based on the assumption that the starting point of development is the individual's subjective experience. Given subjective experience, the individual must infer and construct his or her understanding of others and the world. This perspective has been termed 'a split position' because it assumes that the child is encapsulated in his or her own subjective experience and thus separated from others and the world (Overton, 2015). The problem that follows from these starting assumptions concerns how to figure out that the other bodies observed also have minds like oneself. This is known as 'the problem of other minds' in philosophy. For example, this problem arises for Descartes (1596–1650) when one had to figure out whether the sight of something that looked like a person was really a human being or just an automaton (which were very popular in his lifetime):

> So I may by chance look out of a window and notice some men passing in the street, at the sight of whom I do not fail to say that I see men …. And nevertheless: what do I see from this window except hats and cloaks which could cover automata? (Descartes, 1960, p. 89: first published in 1641)

A next step is to assume that this problem from philosophy is exactly the problem that young children face in coming to understand their social world. This is a taken-for-granted, static, approach and it results in various theories regarding how children come to understand their social world (see Chapters 5, 10 and 11). This set of preconceptions affects the way all of the topics in this book are investigated.

The Saint Augustine/Cartesian/split/cognitivist approach assumes that there is already a world, adult-like and ready-made, that the child then has to make sense of from a somewhat detatched perspective, like an interested observer. This is epitomised by the frequent references to the idea of the child-as-scientist (Gopnik, 1996), in which the detached child observer makes hypotheses about the world. This individualistic approach has been common in psychology and many, but certainly not all, approaches in cognitive science. If the mind already exists ready-made then this not completely a developmental approach, because the child is assumed to be a scientist from the start.

The second, contrasting, range of theories is based on an alternative worldview beginning from the assumption that the person is always actively directed to and immersed in the world. According to this view, mental contents are not something that occur to the person because they are triggered by some input, but instead the person actively creates these contents in the context of his or her goal-directed pursuits. Furthermore, by virtue of being related to the world, the person is also always directed toward others, and meaning

and mental content emerge in the context of social interaction that revolves around objects in the world. Proponents of this view suggest that development starts with the infant's actions or interactions because, they argue, it is inappropriate to presuppose that the newborn infant can 'think'. In order to understand how cognitive processes develop, it is essential to start with the baby's actions in the physical world. Later gestural communication develops as infants learn about their social world. Language is then built on this early communication and linked to the development of social understanding, including moral development. Such approaches are less well represented in most textbooks.

One way to introduce this alternative worldview is to consider Donald Winnicott's (1964) famous statement that there is no such thing as a baby. His point in making this apparently outlandish claim is that the baby does not and cannot exist in isolation. Instead, she is embedded in a complex web of interrelations with other people – indeed these are vital for the infant's very survival. Parents and other caregivers structure the new baby's life (although by crying, fussing, and filling diapers [nappies] babies also structure their parents' time). So Winnicott's point is that it becomes difficult to draw a clear boundary between parent and child (he wrote exclusively about the mother as he lived in a more sexually divided and sexist historical period). For example, the infant's line of vision and her focus of attention is determined by how she is held. This experience results in her learning about certain aspects of her world and this, of course, shapes her neurological development. From this perspective we write about bi-directional processes in which each actor (e.g. parent and child) influences the other's actions and elicits particular experiences (e.g. an infant looking at the adult's eyes may elicit a busy parent's interaction, albeit unknowingly).

From this perspective, infants develop an understanding of the world within their embodied interaction with the physical and social world. Over repeated episodes they develop expectations about what will happen in particular interactions. That is, they learn the interactive potential of their world, including that of other people. Thus, they anticipate how others will respond to their actions and they learn how to coordinate their actions, like cooing, with parents, and engage in the turn-taking sequences of language. Taking the infant's action and interaction as a starting point, these theories are based on what is often termed 'a process-relational worldview'. They are also referred to as action-based, constructivist, relational, embodied, enactive, or interactive theories. We tend to label this approach as 'a relational developmental systems perspective', partly because of the link to developmental systems theory in biology. This is an attempt to avoid the dictomomy between biological and social factors discussed further in the next chapter.

To sum up the section so far: many authorities in developmental psychology argue that the first worldview described above is a taken-for-granted perspective of seeing babies as separate from the world (Lerner, Agans, DeSouza, & Hershberg, 2014: Overton, 2015). The second perspective (process-relational) is that taken by a researcher who has stepped out of the armchair/philosopher perspective to look closely at what is actually happening. That is why the focus is on the process of how we can explain the outcome. Thus, the second perspective would describe the philosophical assumptions of

the first as 'adultocentric' as it posits a baby (or child or adult) as somewhat detached from the world. The second perspective depicts itself as more complex and embedded in social relationships, and it is the worldview we emphasise in this book.

Let us illustrate how topics look from these two contrasting perspectives. Suppose we consider one of the topics in this book: how children learn about other people and develop social understanding. Well, one idea might be that babies see other people walking around doing things and they have to figure out that these bodies are not just robots and that they have minds and thoughts just like the baby's own thoughts. That is, it is assumed that infants face the problem described by Descartes in the quotation cited above – 'the problem of other minds'. For philosophers this might seem reasonable and it is a common view based on ancient ideas. But it assumes the infant or child has knowledge of their own inner states, a first-person, subjective experience, and the problem they are faced with is figuring out other people. This perspective is taken by Temple Grandin (e.g. 1986) in an exercise to understand her own autism.

However, if the baby is trying to figure out other people and perhaps wonders if they also have minds, then this perspective actually already implicitly assumes that the baby has a mind and can think to begin with. So it has already been smuggled in the mind when that is what it was supposed to explain. In fact, the whole way of setting up the problem the baby faces also smuggles in possible answers. This is why it is essential to examine the assumptions that theorists begin with. If we just begin from those assumptions without examining them we are doing philosophy and theory, but it is just invisible.

Another topic with which to illustrate the contrast between worldviews is the development of communication, a crucial and central topic in this book and in understanding human development. In studying the development of communication we could ask, 'what is communication for?' The obvious answer might seem to be 'to express ourselves!' However, we should more cautiously recognise that this already presupposes a mind with something to say, something to express. So this sidesteps the actual problem of explaining development. As described in Chapter 5, from the perspective of the process-relational worldview, the development of communication can be explained through the increasing coordination of activity between infant and adult.

The two families of theories, or worldviews, also differ significantly regarding the role biology is assumed to play. For example, there have been many recent claims that knowledge and thinking are innate or 'hardwired'. In order to be able to critically evaluate such claims we will review recent work on genetics, neuroscience, and evolutionary theory in the next chapter. Such work suggests that it is a long process to get from genes to thinking, and that claims of thinking being 'hardwired' may not be biologically plausible. This suggests that the meaning of the term 'innate' needs to be more carefully examined. From the perspective of the second group of theories, biology plays an equally important, but different, role. From this perspective, the meaning on which human forms of thinking is based emerges from social activity, and therefore cannot be purely individual. Biology plays a crucial role in these approaches in structuring the experience through which children

develop, and patterns of neural interconnectivity are formed within such activity. In other words, the point is not simply a rejection of an individualistic approach to be replaced by purely social approach, which is equally problematic. Instead a third option is a relational constructivist approach in which biology and social levels are interwoven and cannot be clearly separated. In the context of biology, this approach is referred to as Developmental Systems Theory. From this perspective, the biological characteristics of the human infant elicit the social and emotional interactivity in which humans develop.

In explaining the development of children's thinking, a relational developmental systems approach includes all levels from the biology of genetics and neuroscience to the forms of interaction children are engaged in – this is a cell-to-society, and genes-to-justice approach. This sort of approach is becoming influential in cognitive science in general. It is present in developmental psychology, both in classical theories and current approaches, but it is under-represented in most textbooks (Lerner et al., 2014: Overton, 2015). The idea of a system has a long history. For example, there are roots in Aristotle's view that the whole is more than the sum of its parts. This developmental approach also has a long tradition in the history of ideas with classic developmental theorists such as James Mark Baldwin, Heinz Werner, Jean Piaget, and Lev Vygotsky, as well as philosophers such as Charles Sanders Peirce, George Herbert Mead, and Ludwig Wittgenstein (see Bernstein, 2010; Overton, 2015).

Unfortunately, it is difficult to use only one name to refer to these two contrasting worldviews because any of these terms can be, and have been, used in multiple ways. Cognitivists describe themselves as constructivists, and individualists label relational-process thinkers as individualistic. Therefore, readers must gain some understanding of the two worldviews so that they can recognise these approaches independently of the labels used.

The centrality of relations can be found in a number of theoretical perspectives. In Western scholarship the focus tends to be on individualism and independence rather than interdependence, but at the same time the theme of the importance of communities and social networks can also be seen (Sprintzen, 2009). A relational approach is more central from the perspective of a Canadian First Nations worldview and approach to justice in terms of restoring healthy relationships (Ross, 2006). A relational view of justice has important implications for the law (Llwellyn, 2016), and a relational approach can also be applied to social policy and practice (Hankivsky, 2004).

Although there is concensus that social interaction is important, there are two ways of thinking about interaction. The first is that the starting point is the pre-existing environment and individual which then interact. In contrast, the second is that development is based on many levels of bi-directionally interacting factors and the environment and individual do not pre-exist separate from each other, instead, they mutually create each other. That is, from a relational perspective interaction is primary. From the perspective we take, children determine their environments due to their sensitivities, and their actions bring forth or elicit aspects of the environment in which they develop skills. These skills, in turn, can elicit more complex experience in which the child develops further.

We acknowledge that in grouping theories into two large families we are simplifying, and that in fact the situation is not so black and white. However, for our purposes here of introducing theories and worldviews we feel that it is a useful first step in learning about the development of thinking.

1.3 VIEWS OF KNOWLEDGE: CONSTRUCTIVISM

The two worldviews described above also entail contrasting views of knowledge, that is of how children come to understand the world they experience. Why should developmental psychologists be concerned with views of knowledge? Isn't it obvious that we just look at things and we learn about them? Although we have the experience of doing this, it is misleading and neglects the process infants may go through to develop such experience. This view that learning about the world is just a simple passive process of seeing follows from the individualist theories that we have described above, and is what the American pragmatist philosopher and educationalist John Dewey (for discussion see Bernstein, 2010, Chapter 3), criticised and labelled a 'spectator theory of knowledge'. It is also similar to what the Swiss scholar Jean Piaget (e.g. 1970) referred to as a 'copy theory of knowledge', That is, the idea that we learn about the world through passively forming copies of it. Reality is impressed on the mind – like the impression of light on the photosensitive film in a camera, or an impression on a wax tablet. The knower comes to understand the world simply through observation.

Children do learn about the world they encounter and they are born with important potentials for interacting with this world and learning. We do get better at interacting in the world. We do not constantly bump into things, for example, and our understanding of the spaces we move through is the result of several developmental achievements. We have learned through experience what happens as we act in the world. This view of how knowledge develops is *constructivism*. The child actively constructs the known world; the knower assimilates her experience to structures (i.e. repeats old skills and routines in different circumstances) and also accommodates (i.e. learns new ways of overcoming intellectual challenges). For example, a baby playing with a simple object such as a cup can discover what she can do with it. She can hold on to it and bring it to her mouth to suck and she begins to understand the cup in terms of these actions, of what she can do with the object, and so when she sees it she can anticipate the potential actions and results. The world is known through the organisation of activity (e.g. Müller, Overton, & Sokol, 1998). These views of knowledge and representation (i.e. how we acquire knowledge of the world) will be important in the rest of the book.

SUMMARY AND CONCLUSION

We have introduced the topics to be covered in the following chapters in this book. In reviewing these areas of research we introduce the various relevant theories, and discuss

the debates surrounding them. We point out that these theories are based on sets of preconceptions, or worldviews, and theories can be evaluated based on the assumptions they start with. The theories in each topic area can be usefully grouped into two contrasting families. These worldviews underlie theories in each of the topic areas to be covered so they will come up again and again.

One worldview on which a family of theories is based starts from individual minds and then attempts to explain how such minds come to know about each other and the world. The contrasting process relational worldview starts from individuals in relation to others, and thus begins from the social process. From this relational developmental systems perspective the task is to describe how communication and minds emerge from this social process. This approach explains the mind in terms of thinking as the outcome of a social process.

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2 THE ROLE OF BIOLOGY IN PSYCHOLOGICAL DEVELOPMENT

LEARNING OUTCOMES

By the end this chapter you should:

- Understand the debate regarding the roles of nature and nurture in development and views regarding how to resolve that debate.
- Be able to evaluate the biological plausibility of claims of innate knowledge, including whether cats raised with rats are good at hunting rats.
- Have an understanding of the role of genes in the human developmental system.
- Be aware of the study of epigenetics, regarding how genes are expressed, and the new field of sociogenomics concerning social influences on gene expression.
- Understand the distinction between predetermined and probabilistic epigenesis.
- Be aware of plasticity in brain development.
- Understand that genes don't completely determine brain development but, instead, neural pathways are shaped through experience.
- Be able to think about the relations between psychology and neuroscience, and the role of the brain in thinking.
- Be able to evaluate neuroscience approaches to development, contrasting approaches that interpret the brain as an information-processing device with current arguments and evidence that perception is best understood as action plans in the brain, consistent with an action-based constructivist approach.

One of John Lennon's teeth was recently purchased for over 30,000 dollars by a dentist who later revealed that he hopes to clone Lennon if DNA can be extracted from the tooth. He then plans to give guitar lessons to the cloned Lennon (*Rolling Stone*, 21 August 2013). Lennon had given an extracted molar, probably a wisdom tooth, to his housekeeper for disposal, but she kept it in her family and it was auctioned many years later (*Daily Mail*, 9 April 2014; *Huffington Post*, 25 August 2013). There are difficult ethical and legal issues with the plan to clone John Lennon and, ironically, even if this were possible, his well-known rebelliousness might well put an end to these carefully laid plans. But this story is of interest here because this idea does seem to follow from widespread claims made in the popular press about genes, and even in the scientific literature about innate abilities and 'hardwired' traits. This chapter is about why this whole process of getting from genes to the adult person is much more complex, and how a host of biological as well as social factors in addition to genes are crucial in understanding human development.

There are many current claims regarding the role of biology in explaining the development of thinking, and in order to understand and evaluate these positions, it is necessary to know something about current work in biology. This knowledge is essential in evaluating recent positions that appear to have a biological basis, such as claims regarding innate knowledge. We consider the biological plausibility of such views in light of current genetics and neuroscience.

It would be misleading to entitle this chapter 'Biological Approaches to Psychology' because any theory in psychology requires a biological side to the story. Theories, however, can differ radically in how these relations are conceptualised. The two worldviews (sets of philosophical preconceptions) introduced in the previous chapter influence thinking about biology in two ways that we discuss in this chapter. The first issue concerns the nature and development of human thinking and whether it is possible for knowledge and forms of thinking to be innate. From the perspective of the cognitivist or individualist worldview, claims are made that some aspects of knowledge are innate. In contrast, from the developmental or process-relational position, it is argued that forms of thinking develop. It is essential to be aware of the shift in biology in the last several decades. Developmental science is currently experiencing a shift in ways of thinking, moving away from a gene-focused view of instinct and innate knowledge, toward tracing the development of forms of activity and thinking emerging from biological characteristics in a bi-directional interaction with multiple levels of environment (Greenberg, 2014b; Lickliter & Honeycutt, 2015). Even a rudimentary understanding of genetics seems to indicate that it is an incredibly complex process in getting from genes to thinking and there is nothing predetermined in this process (Fisher, 2006; Meaney, 2010).

The second issue concerns the role of the brain in thinking. Obviously, the brain is essential in explaining human thinking. But given this, it is still possible to interpret the role of the brain in cognition in contrasting ways from the perspectives of different worldviews.

The cognitivist perspective assimilates neuroscience to the information-processing and computational view of the mind, according to which the brain is assumed to process input. The result is an output that we refer to as conscious experience or action. From the developmental or relational-process perspective, the brain as part of the nervous system is the organ that expands and makes more complex the child's relation to the world and allows for learning about the interactive potential of the world.

2.1 NATURE, NURTURE, AND FORMS OF INTERACTION

How thinking develops is the problem we grapple with in this book. In explaining the human ability to think, answers tend to fall into two types, focusing either on biological or social factors – nature or nurture. The study of human development is often cast in terms of a contrast between nature and nurture, a debate that was already ongoing among the ancient Greeks in the fourth and fifth centuries BCE (Karmiloff-Smith, 2015). Use of the terms and the separation between nature and nurture can be traced to 1582 when a British teacher, Richard Mulcaster, discussed the ways in which they work collaboratively in child development (West & King, 1987). That collaborative notion, however, was transformed when Sir Francis Galton (1822–1911), Darwin's cousin, set the terms in opposition to one another (i.e. nature vs nurture). This is the way they are more commonly conceptualised (Spencer et al., 2009). It is also part of how we often talk about children's characteristics concerning what they are born with compared to what they have learned.

Unfortunately, innateness is a rather ill-defined term that can have very different meanings. For example, Matteo Mameli and Patrick Bateson (2006) discuss 26 different definitions of innateness. Broadly, the most important conceptualisations in this context are that a trait can be considered innate (a) if it is not learned; (b) if it is present at birth; (c) if it is genetically determined; and (d) if it is highly heritable. However, as Mameli and Bateson show, none of these definitions identifies a coherent concept of innateness. The fact that a trait is present at birth does not rule out that it has been acquired in the course of prenatal development (Gottlieb, 1997; Spencer et al., 2009). The idea that innateness means that a trait is genetically determined is also too simplistic 'because no phenotype is such that only genes are needed for its development. Genes by themselves don't do anything' (Mameli & Bateson, 2006, p. 158). The idea that innateness implies a lack of learning suffers from the fact that learning is a diffuse and ill-defined notion. The problem with the idea of heritability is that it refers to the variability of a trait in a given population at a particular point in time. As a consequence, traits that are invariant in a population (e.g. walking on two legs) cannot be innate, and changes to the composition of the population can change the heritability of the trait in an organism – both notions that run counter to what we usually imagine when we think that some trait is innate.

Notwithstanding problems with the definition of innateness, the roles of nature and nurture in development remain a hot and controversial topic. Researchers argue that a particular amount of individual differences in a trait is genetic (Friedman et al., 2008), that a gene for a particular trait or disorder has been identified (Gopnik, 1990), and that a specific skill emerges so early in development or is so complex that it could not possibly be learned (Margolis & Laurence, 2013). Even though most researchers would assume that both nature and nurture play some role in development, there is still considerable difference between positions regarding how to conceptualise their relative importance and how to relate them to each other. On one hand, there are those who argue that it makes sense to quantify the contribution of genes compared to environment to individual differences in a trait (Plomin & Simpson, 2013). This field of study is called behaviour genetics or quantitative genetics, and uses research designs such twin and adoption studies. On the other hand, some maintain that it is not meaningful to separate genes and environment in order to calculate their relative contribution to individual differences because the two are inextricably linked (Meaney, 2010).

A different approach to studying the influence of nature on development is taken by molecular genetics, a field of study for the investigation of how DNA segments are associated with psychological characteristics. A number of different approaches are used to link heritable traits to variation in DNA. For example, linkage analysis tries to find variants of DNA sequence (markers) that co-occur with the presence of a disease in families with both affected and unaffected members. Linkage analysis has been successfully employed in the case of disorders that are caused by single mutations that have large effects (e.g. Huntington's disease, which emerges in middle age and leads to rapid cognitive decline and death), but it has not been successfully employed for more complex disorders that involve many genes with more modest effects (e.g. schizophrenia). A more powerful method to discover genes associated with particular traits or disorders is the genome-wide association (GWA) study. GWA studies use DNA microarrays containing probes for a million or more single-nucleotide polymorphisms (SNPs); nucleotides are the basic building blocks of DNA. Even though GWA studies have identified new locations of DNA sequence that are related to complex physical traits and disorders, the amount of variance explained by SNPs is rather small across studies, and SNPs identified for cognitive abilities and personality traits do not replicate across studies (Manuck & McCaffery, 2014). The small amount of variance explained by SNPs (even taken together, all relevant SNPs rarely explain 10% of variance in trait variation) has led to some disillusionment among proponents of molecular genetics. The difference between the small amount of variance explained by SNPs and the relatively large genetic influence (up to 80%) usually reported in behaviour genetics studies has been referred to as 'missing heritability problem' (Maher 2008). Several solutions to this problem have been suggested (Manuck & McCaffery, 2014); however, we think that it points to deep-rooted and incorrect assumptions about the functioning of genes and that a new way of thinking about the role of genes in development is required to solve this problem.

Researchers claiming that some forms of thinking are innate might appear to be providing a rigorous scientific and biological explanation of thinking. But the problem is that such claims depend on biological assumptions in getting from the functioning of genes to forms of thinking. In order to evaluate these claims, it is necessary to know something about biology. To give a bird's-eye view of the issue we can roughly group approaches to biology into two families. One is a gene-centred approach in which the claim is that forms of thinking are 'specified by our genetic program' (Pinker, 1997, p. 21). Here the idea is that genes contain a plan or program that determines developmental outcomes. Although phrases like 'genetically determined' are avoided these days, that idea may still lurk behind more ambiguous wording alluding to biological foundations or claims that infants are 'endowed' or 'equipped' with certain forms of knowledge. But the biological process resulting in whatever is being endowed tends to be left unspecified. The second approach is known as developmental systems theory, which we turn to below.

There has been considerable debate about the extent to which infants are born with knowledge ready to understand aspects of their world. Elizabeth Spelke and Katherine Kinzler (2007, p. 89) 'believe that humans are endowed with a small number of separable systems of core knowledge for representing objects, actions, number, and space', as well as possibly 'a fifth system for representing social partners' (see also Spelke, Bernier, & Skerry, 2014). Another approach also makes strong claims about thinking being innate, but argues that this thinking is more specific to solving particular problems. This approach is known as Evolutionary Psychology, according to which the human mind is claimed to consist of a large collection of innate modules that have evolved to solve particular problems that existed when humans were evolving in our ancestral environment (Cosmides & Tooby, 2013; Pinker, 1997).

Evolutionary perspectives on understanding and explaining human behaviour have been common in developmental psychology and informed the theorising of major developmental psychologists such as James Mark Baldwin (1896), Heinz Werner (1948), and Jean Piaget (1967/1971). However, what is referred to as Evolutionary Psychology is a more narrow research programme founded by Leda Cosmides and John Tooby that makes a number of problematic assumptions about the human mind and evolution. First, Evolutionary Psychology subscribes to the computational theory of mind according to which the mind is an information-processing system (a formal symbol manipulator). Second, it treats the mind as a collection of separate domain-specific, special purpose computational systems or modules. These include 'face recognition systems, a language acquisition device, mind-reading systems, navigation specializations, animate motion recognition, cheater detection mechanisms, and mechanisms that govern sexual attraction' (Cosmides & Tooby, 2003, p. 63). Third, it considers the computational systems as adaptations, the result of random mutations that proved to be advantageous (i.e. enhanced fitness) and therefore were selected. Fourth, the computational systems have evolved to solve recurrent problems (e.g. food aversion, mate selection, way finding) that our ancestors, living in small hunter-gatherer bands, encountered during our evolutionary past in the Pleistocene conditions

(a period that lasted approximately from 2,000,000 to 10,000 years ago), and they still guide our behaviour today, even if they may no longer offer a selective advantage in our present environment.

Evolutionary Psychology has been criticised for a variety of reasons (e.g. Sanders, 2013). First, it simply assumes that the computational mechanisms are considered as adaptations (Richardson, 2007), leaving them untestable and making further or deeper analysis very difficult. Second, the idea that the computational mechanisms are adapted to the Pleistocene has been questioned (Dupré, 2012). Third, the computational view of the mind has itself been criticised (e.g. Heil, 1981). Fourth, it has been pointed out that we do not know the world our ancestors inhabited and thus can only tell 'just-so-stories' about the recurrent problems they faced (Buller, 2005a). This characterisation is from Rudyard Kipling's (1902/1962) *Just So Stories*, a series of apocryphal children's bedtime stories purporting to explain 'how the lepoard got his spots' and 'how the camel got his hump' and so on. Finally, the empirical evidence produced by evolutionary psychologists to support their theory has been subjected to a scathing criticism (Buller, 2005a, b).

A final line of criticism directed at Evolutionary Psychology is that the notion of modularity is flawed (Prinz, 2006). The notion of modularity can be traced back to the nineteenth-century movement of phrenology and its founder Franz Joseph Gall. Gall argued that human faculties such as thinking or the love of offspring are located in particular areas of the brain and that the strength of the faculty was indicated by the size of the brain area. Gall's phrenology was soon discredited, but more recently Jerry Fodor (1983) revived the idea of modularity. According to Fodor, one essential feature of modules is that they are informationally encapsulated in that even if you know that your friend will not poke you in the eye, this information cannot stop you from automatically blinking in response to a finger approaching your eye. Although Fodor entitled his book *The Modularity of Mind*, he thought that peripheral (e.g. perception, motor processes) but not central (higher cognitive abilities such as thinking) processes are modular. Since Fodor's book, the notion has changed to include conceptual modules specialised for particular domains such as the physical world and the social world that are somewhat separate from other systems (Sperber, 1994). This position was expanded by Steven Pinker in his book *How the Mind Works*, in response to which Fodor – clearly unhappy with the idea of conceptual modules – published a book entitled *The Mind Doesn't Work that Way*. Although this is a complex debate that is difficult to summarise because there are many positions, the term is now used primarily to discuss claims of innate domain-specific knowledge, a position we evaluate in this chapter. However, the claim from Evolutionary Psychology is that these modules evolved to solve particular problems faced by our ancestors. But this assumption of the environment as presenting problems has been criticised by Richard Lewontin (1983/2001) who points out that organisms' characteristics influence the environment they experience. Furthermore, the notion of modules assumed by Evolutionary Psychology has been modelled on Chomsky's claims about language

being based on an innate mechanism. However, Chris Moore (1996, p. 613) points out that it is difficult to argue that language evolved to solve a particular problem because it has many functions, such as:

> Shall we have Chinese or Italian tonight? (foraging)
>
> Has anyone ever told you you have beautiful eyes? (mating)
>
> Look both ways before you cross the street (parenting)
>
> NO TRESPASSING (territoriality)

In most of the areas of research covered in this book we describe how some researchers make claims about innate knowledge, that is, about infants being born with certain forms of knowledge such as concerning the social world (Gopnik & Wellman, 2012; Leslie, Friedman, & German, 2004; Onishi & Baillargeon, 2005) and morality (Bloom, 2010, 2014; Hamlin, 2013). Of course, researchers making such claims acknowledge that there must be further development. But these are still strong claims that are based on biological assumptions and therefore they need to be carefully evaluated.

Instead of being new, attempting to understand human development in terms of innate characteristics has a long history and it keeps re-emerging. The Hippocratic School of ancient Greece (i.e. followers of Hippocrates, the father of medicine, in the fifth century BCE) explained human development by assuming that the fertilised egg contains a miniature adult. This is not a truly developmental explanation because it claims that there is only an increase in size and fails to explain how structures form. Aristotle, however, questioned this and argued instead that structures gradually develop rather than being preformed. Of course, no one currently claims that there is a small person in an egg that just gets bigger, but the idea that the information for the adult is already contained in the fertilised egg in the 'genetic program' persists, and this is a variation on the ancient idea of preformationism (i.e. the belief that we are already formed and start as tiny versions of ourselves) (Lickliter & Honeycutt, 2009, 2015).

Some notion of innate knowledge or instinct has a long tradition that can be traced back at least 2,500 years to Greek literature (Beach, 1955). There is a history of this debate in various disciplines. The notion of instincts has also been long debated in psychology. In the late nineteenth century William James (1890) argued in *The Principles of Psychology* that instincts are important in understanding human psychology. The idea of innate instincts and biological maturation due to genes was thought to be a sufficient explanation for human development in the first half of the twentieth century, as proposed by Arnold Gesell (1945), but biological inheritance was rejected by John Watson (1924/1970) who emphasised learning instead. The idea of instincts to explain reoccurring patterns of activity re-emerged in ethology in the work of Konrad Lorenz and Nikolaas Tinbergen. In contrast, the biologist Daniel Lehrman (1953/2001) argued that instincts

are not an adequate explanation, and, instead the development of the behaviour must be explained (a point we come back to below). In anthropology, Franz Boas and his student-colleagues Margaret Mead and Ruth Benedict also rejected instincts and emphasised the role of culture in human development (Laland & Brown, 2011). History is repeating itself, and once again claims of innate knowledge are re-emerging. This legacy still has an influence today, which is why this chapter is necessary at the beginning of the book.

It might seem reasonable to claim that babies are born with knowledge because isn't this the case with other species? A common example used by psychologists is that spiders are claimed to have innate knowledge of how to spin a web so why should it be surprising that human babies have innate knowledge? Well, ironically, claims about spiders knowing how to spin webs tend to be made with no reference to the scientific research on spiders. If we consider a group of spiders about which something is known, the story gets more complicated and more interesting. Portia spiders don't spin webs but they are known for their complex hunting strategies. Are these complex strategies innate? These spiders have tiny brains, literally the size of a pin. Their hunting behaviour is not based on innate knowledge but rather on the types of eyes they have and where these are located on their bodies. That is, the complex behaviours they exhibit have to do with the nature of their embodiment rather than innate knowledge (Barrett, 2011). So, is this ability to hunt innate? It depends on what is meant by innate. These spiders regularly show complex behaviours that emerge from their biological characteristics in interaction with their typical environments. That is, the behaviours regularly emerge in the spiders' developmental system.

Claims regarding innate knowledge rest on biological assumptions and it has long been argued that researchers making such claims should feel obliged to ensure that this assumed process is biologically plausible (Hebb, Lambert, & Tucker, 1971). However, the more that is learned about biology the less plausible a simple gene-based mechanism seems. Such claims fit with views about inheritance and brain development that were dominant in biology forty years ago. But they no longer fit with contemporary findings in developmental neurobiology. Instead, the more recent view in this subdiscipline is that human brains develop through a dynamic process involving the influence of experience (Stiles, 2009; Stiles, Brown, Haist, & Jernigan, 2015). In this chapter we aim to give readers enough knowledge of current relevant work in biology to evaluate claims that human infants are born with innate knowledge.

What is assumed in claims that some behaviour is innate? Consider an example suggested by Noam Chomsky (2007, p. 12). He stated that the 'pecking of a chicken' is an example of 'a genetically determined instinct'. This is because chicks don't seem to learn this action pattern, but all of them do it, so it seems that it must be 'genetically determined'. This claim seems reasonable because chicks start the coordinated actions of pecking and eating within a few hours of hatching – so early in life that it appears unlikely to be based on learning.

However, this is all speculation without being based on any empirical research, and indeed, without the awareness of previous findings on this topic. In fact, the Chinese comparative

psychologist Zing Yang Kuo had already done the careful research in the 1920s and 1930s providing a complex developmental analysis, showing how this action pattern is not simply genetically determined. Kuo, working without the benefits of modern sensing equipment, came up with a method for examining development within the egg by creating a window in the shell in order to see the processes occurring within the egg. Through examining development in 3,000 live samples he found that this activity pattern emerges as the chick is developing in the eggshell. At about day 3 its heart starts beating, causing a head movement that sets up a motion resulting in the development of the pecking movement (Greenberg, 2014a). So, although genes are involved in everything, they alone do not determine this movement, and pecking movements would not necessarily emerge without the chick developing within the constraints of the eggshell along with the beating of the heart, among other factors (Greenberg, 2014a; Kuo, 1967; Lehrman, 1953).

What this example shows is that we should not be satisfied with simple claims that some traits are 'genetically determined' and instead it is important to trace very carefully the actual developmental emergence of a behaviour. This should perhaps be the mantra of developmental psychologists. The constraint of the eggshell is one level of the environment experienced by the developing chick. For humans, especially, we need to be aware of the influence of levels of the social environment on development. It is crucial to think about the whole developmental system in which human infants develop.

Consider another example, also studied by Kuo, which is a step closer to social interaction. It might seem that cats have an innate rat-killing instinct. However, Kuo found that kittens raised with rats don't kill rats. In fact, these cats may form emotional bonds with not only their rodent 'step-siblings' but also other members of that species. So, the pattern that cats raised in typical environments tend to kill rats is not the product of a simple instinctive impetus. As Kuo (1930, p. 35) put it, 'if one insists that the cat has an instinct to kill the rat, I must add that it has an instinct to love the rat, too'. A more complex developmental story is required to understand cats' hunting behaviour since simple biological maturation is not sufficient. This is certainly not to deny the role of biology in the typical emergence of this skill, but instead to point out the need for a more comprehensive explanation (Kuo, 1930, 1938; Lickliter & Honeycutt, 2015).

When we encounter claims that a trait is innate this generally means a developmental account is not yet available. That is, we are owed an explanation (Lickliter & Honeycutt, 2009, 2015). But the problem here is that it is not usually understood this way. Instead, claims of innate knowledge tend to be accepted and thus they block further developmental research because they masquerade as explanations. They are non-developmental. Daniel Lehrman (1953) nicely showed the pitfalls of the nativist approach in his critique of Konrad Lorenz's notion of instinct, and argued that taking a nativist position precludes the exploration of behaviour from a developmental process view. Lehrman provided various examples that appear to support innateness, but actually do not. His main conclusion is that all of these supposedly innate behaviours are not actually tightly integrated and autonomously maturing, but instead are the result of a cascade of ontogenetic

(i.e. developmental) processes such that the organism's developmental change (from one stage to the next) is the product of the interactions that occur between the organism and its internal environment. Current interactions link past developmental stages and future ones.

Any scholar, even those making very strong claims about genes determining traits such as Steven Pinker (1997), must acknowledge that the modules they claim do the thinking do have to *develop*. That is, there is general agreement that there is interaction between biology and the environment, and it is also frequently stated that the nature–nurture debate is over. But these issues still tend to arise even when they have been declared stone dead. What is needed to really drive a stake through the heart of this perpetual zombie is to leave our armchairs and take a close look at the interaction between biological and social factors (Oyama, 2000). This is because there are two ways to think about such interaction. One is to acknowledge that, of course, biology and the environment interact, but that they are pre-existing entities and it is possible to separate them, which means that it is also possible to consider roughly what percentage of each contributes to development or individual differences in development. Behaviour genetics takes this approach. Many researchers also continue to talk about the genes providing the blueprint and the environment doing the tweaking. In other words, there is an interaction between the two separate entities of nature and nurture. Although this may be an improvement, it shows that the dichotomy is not completely dead.

Nature–nurture debates are often presented as disputes between nativism and empiricism, between biology and a 'blank slate' view of the infant (Cosmides & Tooby, 2013; Pinker, 2002). However, as we have argued in Chapter 1, nativism and empiricism are not so different because they share the assumption that the mind is essentially passive. Furthermore, this way of setting up the debate is itself a problem because it already presupposes two separate entities that interact. It tends to be assumed that there are just two positions and the pendulum swings back and forth between them (Allen & Bickhard, 2013). Instead it is crucial to follow Allen and Bickhard's plea and get off the pendulum to take a different position, by setting up the problem in a different way. So, rather than solve the problem we must dissolve it.

Nature and nurture are abstracted out of relations through the use of these words. In fact, nature and nurture mutually create each other, so it is the many levels and types of relations of this mutual creation on which we should focus. Human infants have developed characteristics over nine months in the womb that set them up for further development; their sensitivities at birth create the environment they experience and that they elicit, and this experience then results in further biological development in a bi-directional manner. This results in a very different view of interaction. Developmental systems theorists try to do without the dichotomy by focusing on the relations rather than separable biological and social factors. That is, when we look closely at any aspect of development it is not possible to draw a clear line between biology and social factors because they mutually create each other in a bi-directional manner. If interaction is taken seriously and closely examined, then the notion of pre-existing entities starts to dissolve because biological characteristics

result in a social environment in which neural pathways are developed and babies develop skills with which they can elicit more complex social experience and so on. This mutual influence of biological and social factors continues to interact bi-directionally so that it is not possible to ever clearly separate them. So, from this perspective, it is not possible to see where the biology stops and the social starts.

Infants 'create' their environment through their biological characteristics. This process is best understood by giving an illustration. Babies' visual systems determine what they can see. To cite two examples, the characteristics of human eyes draw infants' attention to eyes and faces, and they cry in response to discomfort. These biological characteristics develop in the womb, and that is another complex developmental story that, unfortunately, for reasons of space, we cannot cover in this book (Moore, Persaud, & Torchia, 2008). We can say that genes are involved as one essential part in the developing system, but only one part, and by themselves they do not determine or control anything. Instead many factors, including social experience influence gene expression, that is, the process by which information from the gene is used in the synthesis of a functional gene product (e.g. protein).

In fact, the more we learn about biology, ironically, the clear line between biology and social levels disappears, and it seems more accurate to say that 'nature is nurture' because social experience such as abuse or chronic poverty can cause biochemical changes to the DNA, resulting in differences in the activity of genes (van IJzendoorn, Bakermans-Kranenburg, & Ebstein, 2011, p. 309). Thus, according to Michael Meaney (2010), separating the influence of genes and environment is a 'rather arcane notion' (p. 41) that is 'inconsistent with even the most rudimentary understanding of gene function' (p. 69). Indeed, claims that genes cause outcomes such as conduct disorder 'drive many scientists slightly mad, since the data are merely correlational and do not imply a cause–effect relation between the genomic variant and conduct disorder' (p. 43).

We will go into further detail in the rest of the book, but for the moment even these very simple examples, overlooking layers of complexity, illustrate how the biology creates the social environment of the child and social experience influences biological development. It is not possible to neatly draw any clear line between the two. That is, the characteristics of the infant's biological embodiment influence the environment of development, the developmental niche in which the baby grows up.

When we consider the complexity of a child growing up it may be hard to avoid thinking that it must emerge from pre-existing information, and then naturally the question arises of where this information would be located. The answer seems to be in the genes, in a 'genetic program' that is set to unfold. It is difficult to avoid the tendency to think of complexity as being preformed somewhere, an assumption made by Parmenides three hundred years before Aristotle in the fifth century BCE. We need analogies to be able to break out of this pattern and think of the complexity of human thought as the regular outcome of a system of interacting factors. Instead of genes as 'blueprints' containing a plan or information for the construction of an individual, think of ecological succession as an analogy. Consider forests, for example.

WHY IS THERE REGULAR DEVELOPMENT IN ECOSYSTEMS?

Mature, old-growth forests on the Pacific northwest coast of North America tend to be primarily Western Hemlock and Western Red Cedar. This is a regular outcome of a complex process, but it is not pre-specified. After a forest fire the first plants to start recolonising tend to be fireweed and then small shrubs and gradually maple trees grow. The trees that can tolerate the shade under the maples tend to be hemlock and cedar. So, they grow and gradually become the dominant species. Thus, simplifying greatly, this type of forest is a regular outcome, given typical climate conditions (which are changing).

This analogy can be helpful in thinking about how something incredibly complex like a forest ecosystem, or a child, can be a regular outcome given typical conditions in the developmental system. That is, the usual outcome of a Hemlock–Cedar forest is expectable, yet it is not pre-specified. With this example we can see a complex system regularly emerging, but it is not pre-specified anywhere. The same goes for human developmental trajectories.

In order to understand the complexities of interaction in human development, it is helpful to think about specific aspects of the process. For instance, consider the simple everyday example of smiling, an incredibly important aspect of what it is to be human that is crucial for interpersonal emotional communication. The importance of smiling can be appreciated simply by paying attention to how we experience someone smiling at us. So, is smiling innate? It is found only in humans. Other great apes may sometimes raise the corners of their lips, but this is not responded to by others, so it does not appear to be a social signal in the way it is in humans. Smiling is also universal in the sense that all humans typically smile except in rare cases involving considerable neurological damage. Smiling also seems to have a universal meaning across cultures. If we walk down a street and someone smiles at us it affects us emotionally, and this would most likely be the same across cultures (Jones, 2008).

Newborn infants smile, even if they are blind, so this does not require any social experience or observation. However, the smiling of newborns is not the same as that of older infants. It is not really a social smile because they do so when sleeping or drowsy. Smiling while awake begins at about 4 to 6 weeks of age when it is in response to various actions of humans but also non-humans and even movements of non-living objects. That is, a baby may smile at a parent but also at a curtain being blown by the wind (Jones, 2008). So, smiling seems to be the result of a startle, a rapid change in the state of arousal. Smiling in adults is linked to happiness, although it has many social uses. Thus, the development of smiling turns out to be a complex interaction of biological characteristics and

social experience. This is shown neatly in Viktoriya Wörmann's study of the emergence of an infant smile in relation to maternal smiling. The pattern was found at 6 weeks in Germany but not until 12 weeks in Nso infants in Cameroon (Wörmann, Holodynski, Kärtner, & Keller, 2014), presumably because the two cultures promote different patterns of adult–infant interaction. At 4 to 5 months, some infants smile when they are in face-to-face interaction, apparently as a social bid to try to restart the interaction with their mothers who were asked to hold a still face (Mcquaid, Bibok, & Carpendale, 2009; this is further discussed in Chapter 5). There is evidence of smiling that is influenced by the social context when children are somewhat older (i.e. between 8 and 12 months). At this point some infants smile while engaged with toys and then turn toward their mother while smiling. But some infants do so less when their mother is preoccupied. These are the same infants who also engage in other forms of early communication such as pointing, suggesting that smiling at this point is beginning to be a communicative act depending on their understanding of the social situation (Jones, 2008). Here we have only mentioned a few early steps in the development in complexity of this important human social act. As adults we are aware of the incredible diversity of forms of smiling in various social situations, and the social information communicated by the smile.

We have suggested that a shift is occurring in thinking about development, from a focus on DNA as determining developmental outcomes to an appreciation of multiple additional biological factors, to be discussed further in the following section. Interestingly, in developing a comprehensive theory of evolution, Jablonka and Lamb (2007) distinguish between four different, yet interacting, inheritance systems that stabilise development but also transmit variations on which selection processes can operate. Specifically, they argue that 'heredity involves more than DNA' (p. 357), and suggest that inheritance systems include, in addition to DNA, epigenetic inheritance and behavioural and symbol-based inheritance systems. Broadly, epigenetic inheritance (which we discuss below) refers to 'inheritance of phenotypic variations that do not stem from differences in DNA sequence' (Jablonka & Lamb, 2007, p. 357). The behavioural-based inheritance system involves socially mediated learning by means of which animals and humans generate traditions. For example, macaque monkeys on the small Japanese island of Koshima have learnt to wash sweet potatoes after this habit was introduced by a young female (but see Tomasello, 1999). The most important symbol-based inheritance system is language, which is also transgenerationally transmitted. Offspring also inherit the ecological niche from their parents. The ecological niche, in turn, influences the development and behaviour of the offspring. There are many examples of niche construction among animals – dam building among beavers, earthworms chemically altering the soil in which they live (see Odling-Smee et al., 2003) – but niche construction has taken on a qualitatively new level among humans.

From Jablonka and Lamb's theory emerges a fundamentally different view of the relation between biology and culture, and of the role of development in evolution. Biology and culture interact in complex ways, in phylogenesis as well as in ontogenesis. Humans, as